Section 1

Process for Identifying Needs

King County's regional conveyance system includes the pipelines, pump stations, and regulator stations that transport wastewater to the regional treatment plants. The conveyance facilities include 42 pump stations, 19 flow regulator stations, and more than 275 miles of sewer lines.

Growth in flow volumes over time, largely due to population and employment growth that increase peak flow projections, is driving the need to address capacity limitations throughout the conveyance system. In addition to capacity concerns, the County's conveyance system is aging and is continually in need of maintenance that includes inspection, cleaning, and repairing to preserve capacity and system integrity. Many conveyance facilities were built over 40 years ago. Over time, these older parts of the system may need to be of rehabilitated or replaced to prevent failures that could result in overflows or backups.

For this technical memorandum, conveyance needs have been identified based on assumptions about construction of the new Brightwater Treatment Plant, projected capacity needs and the current condition of specific conveyance system facilities identified through inspection. The age of system components has also been included to provide information about potentially needed capital investment in the future to repair or replace facilities that may no longer be able to be maintained efficiently.

This section of the technical memorandum provides background information about how conveyance system capacity, condition, and age information was obtained and how it was used to identify needs within the system.

1.1 Conveyance Planning Areas

Due to the size of the King County conveyance system, management, inspection, planning, and needs prioritization have been facilitated by breaking the regional system into ten sub-regional planning areas. These ten sub-regional planning areas are shown in Figure 1-1 below.

Documentation on sub-regional planning areas includes details on specific facilities, local wastewater agencies, and wastewater service basins. Information gathered includes regional and local wastewater planning records, descriptions of the current regional and local facilities, demographics, infrastructure, environment, and governance within each basin. Other information gathered for each sub-regional planning area includes projected growth, data on flows, and known overflows. Ongoing system inspection provides documentation of system condition within the planning sub-areas. All of this information combined forms the basis for determining the overall system planning priorities.

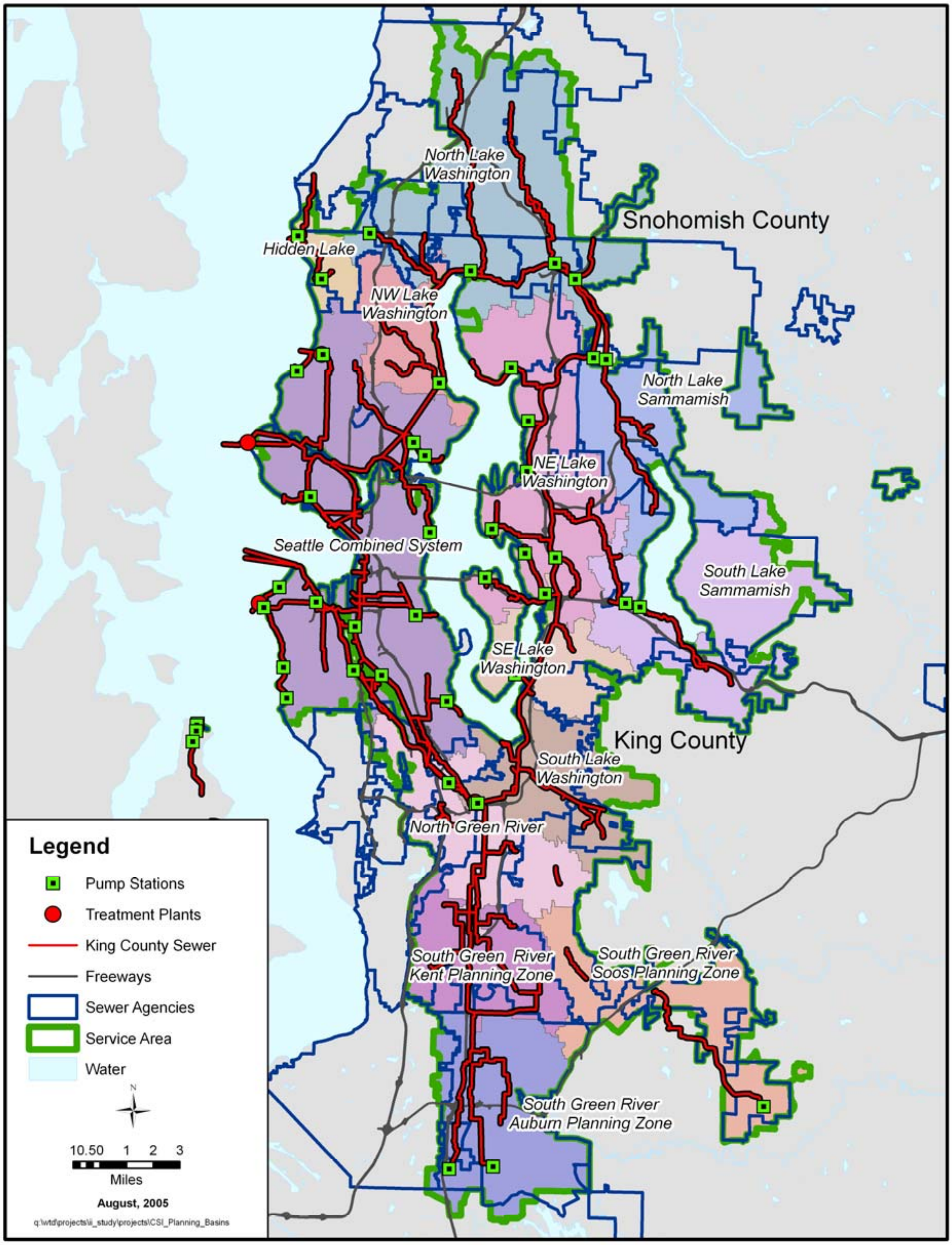


Figure 1-1. Conveyance System Improvement Sub-regional Planning Areas within the WTD Wastewater Service Area

1.2 Needs Based on Capacity

The regional wastewater conveyance system has developed over the last 40-plus years. Most of the system has the necessary capacity to transmit wastewater flows today and in the future. However, some portions of the system are at or near capacity during periods of peak flow.[1] As the region grows over time, these portions of the system and others will not have adequate capacity to transmit peak wastewater flows to treatment plants. Inadequate capacity in portions of the system increases the risk of wastewater backups and overflows during periods of peak flow.

The two factors that drive the need to expand capacity in the conveyance system are regional population growth and infiltration and inflow (I/I) flows within the system. I/I is groundwater and stormwater runoff that enters wastewater collection pipes during periods of rain. Most infiltration comes from groundwater; most inflow comes from stormwater. Sources of infiltration and inflow are identified in Figure 1-2.

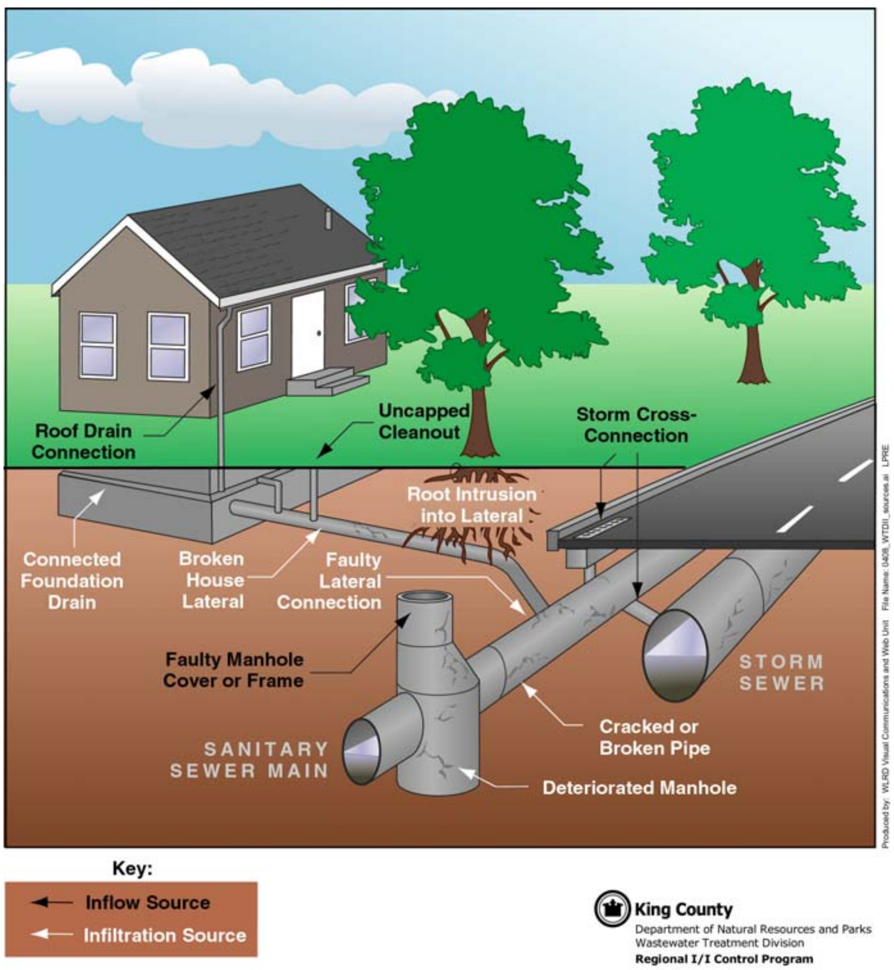


Figure 1-2. Sources of Infiltration and Inflow

[1] Peak flow is the highest base flow and infiltration/inflow expected to enter a wastewater system during wet-weather at a given frequency that a treatment plant and conveyance facilities are designed to accommodate.

Growth in wastewater volume from residences and businesses, or “base flow,” over time is driven by changes in population and employment in the service area, septic conversions to sewers, and changes in water use through conservation efforts. Based on these factors, base flow in the regional service area is projected to grow from approximately 75 million gallons per day (MGD) to over 120 MGD by 2050. Figure 1-3 illustrates the projected growth rate in base flow for the region. Note that the projected growth in base flow through 2010 is relatively flat. This is due to the expected immediate positive influence of water conservation efforts that are currently under way. Projected growth after 2010 assumes that the effects of water conservation will remain constant.

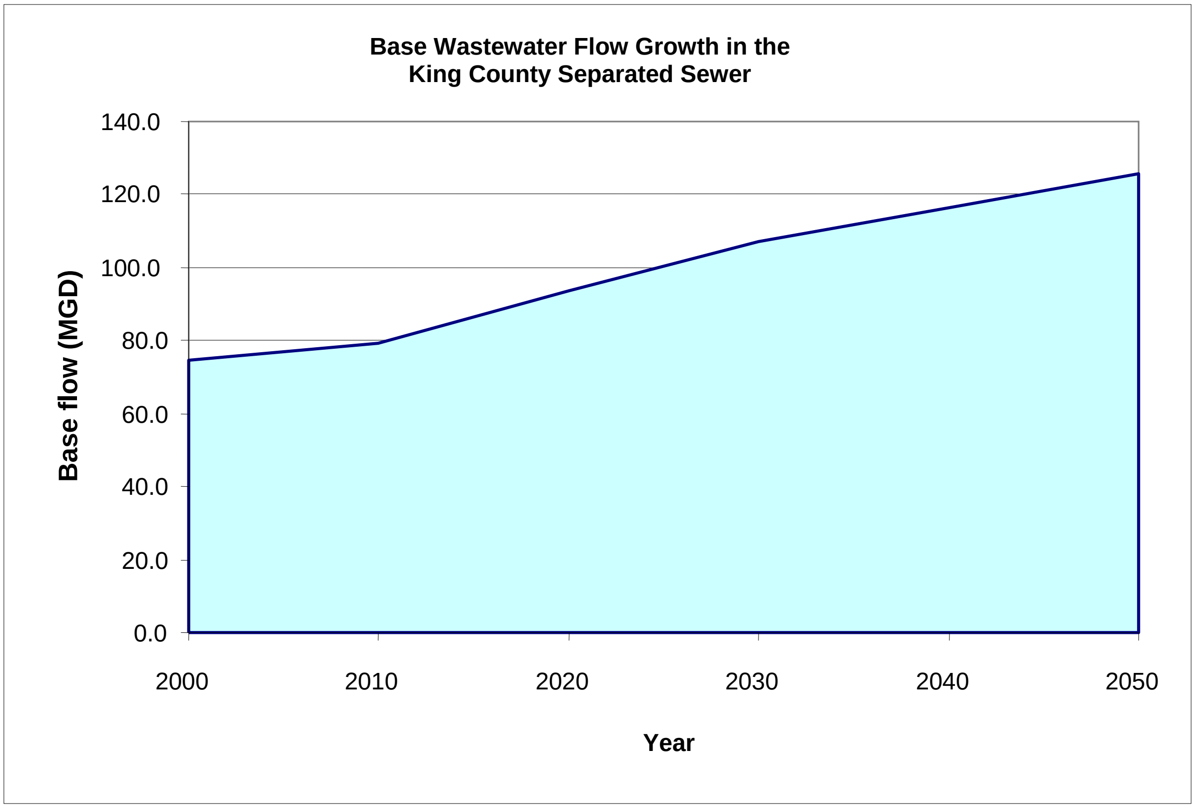


Figure 1-3. Projected Growth in Base Flow

Of the growth factors described above, growth in residential sewered population (from either new development or septic conversions) has the biggest effect on growth in base flow.

The projected peak flow rates are a combination of base flow increases due to growth, existing I/I rates, I/I rates from newly sewered areas, and I/I from degradation of existing and new sewers. Flow projections and sewer capacities are determined with the use of hydraulic modeling and analysis, which uses a variety of data inputs and planning assumptions that are discussed further in this section.

I/I significantly impacts the capacity of the region’s wastewater conveyance and treatment system because it is the largest contributor to peak wastewater volumes that must be conveyed and treated in the wet season. About 75 percent of the region's peak flows in the separated conveyance system comes from I/I [2]. Figure 1-4 contains a typical hydrograph that shows how I/I affects regional wastewater volumes that must be conveyed and treated. As can be seen, flow volumes can quadruple during rain events when the conveyance system must handle base flow plus I/I (the blue line in Figure 1-4).

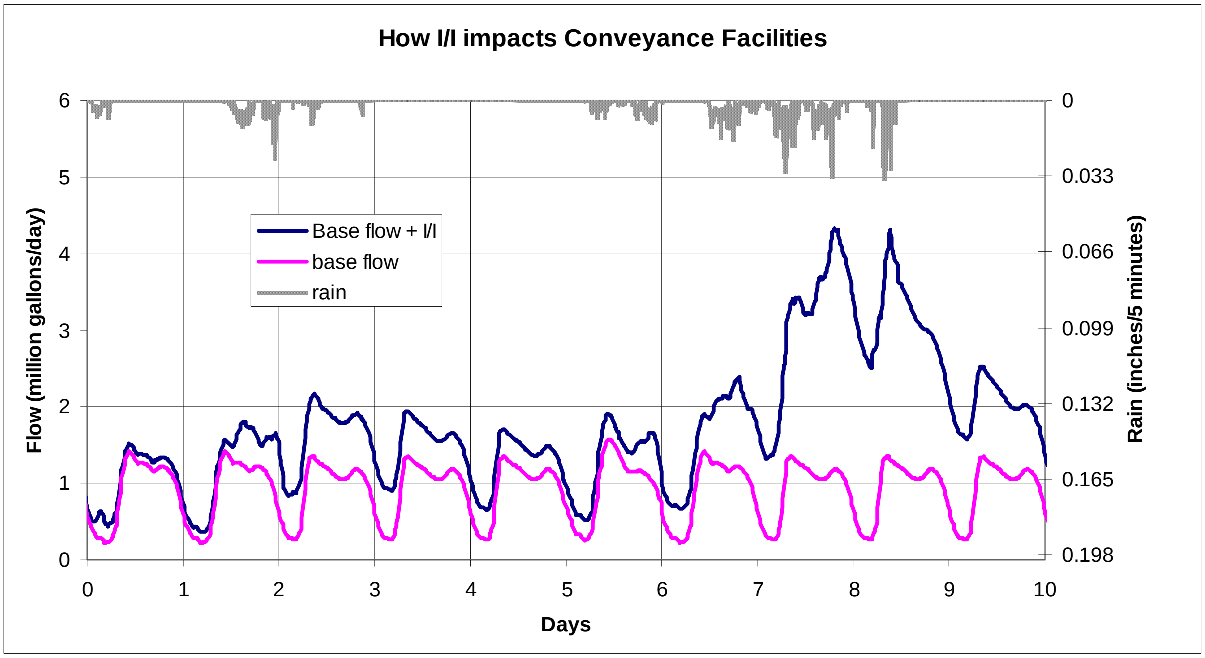


Figure 1-4. Impacts of I/I on Wastewater Flows

> **Basis for the 20-Year Peak Flow Development Standard**
>
> The adoption of the RWSP in 1999 established a uniform development standard for all future development. RWSP Policy CP-1 states:
>
> *To protect public health and water quality, King County shall plan, design, and construct county wastewater facilities to avoid sanitary sewer over flows.*
>
> *1. The twenty-year design storm shall be used as the design standard for the county's separated wastewater system.*

Twenty-year peak flow is the total flow (base flow and infiltration/inflow combined) expected to enter any segment of the conveyance system during wet weather on an average of once every 20 years. As a development standard, King County designs and builds new conveyance facilities to minimize the risk of an overflow or backup occurring in the system by sizing the facilities to accommodate a projected 20-year peak flow event.

To ensure that components of the system are adequately sized for the future the Wastewater Treatment Division (WTD) has chosen 2050 as its design year for all new facilities and facility upgrades. The year 2050 is the projected date when the regional wastewater service area will be fully built out and all portions of the service area will be connected into the wastewater treatment system. This means that facilities are being designed to convey and treat 20-year peak flows

[2] *Regional Wastewater Services Plan, Executive's Preferred Plan;* April 1998, page 14.

projected to occur in 2050. To avoid over-building, facility construction is being phased whenever practical. The effect of applying the 20-year peak flow standard is that certain components of the conveyance system that were built prior to the development of the standard now require upgrades to meet it.

Hydraulic analyses conducted in 2002-2005 based on extensive system-wide flow metering have indicated which components of the regional conveyance system are either at capacity or will be reaching capacity, as defined by the 20-year peak flow standard, between now and 2050. These analyses are documented in the March 2005 *Regional Needs Assessment* (RNA) Report, which identified 63 capital conveyance projects needed through 2050. As documented in this memorandum, the capacity shortfalls that created the need for the 63 proposed projects have been further refined to identify needs based on condition and age of system components. The following section explains how capacity-related needs were determined.

1.2.1 How Capacity Related Conveyance Needs Were Determined

The capacity related projects listed in the 2005 RNA included a combination of projects previously identified in the 1999 RWSP, the 1999-2003 Conveyance System Improvement (CSI) Program, and additional projects identified based on extensive new flow data and sewered population information obtained and analyzed during development of the Regional I/I Control Program. Hydrologic and hydraulic modeling analyses conducted for the Regional I/I Control Program, using system-wide flow metering data collected over two wet seasons, was the basis for updating the list of projects needed through 2050. The modeling analyses and flow data are discussed briefly below. A more thorough discussion can be found in the RNA. Identified needs based on capacity are listed in Section 2 of this memorandum.

1.2.1.1 Overview of Modeling Analyses

Using commercially available hydrologic and hydraulic modeling software, MOUSE™ (Modeling of Urban Sewers), and various data about the existing conveyance system that were collected as part of the Regional I/I Control Program study, the County was able to project peak flows into the future.

Modeling Term Definitions:

Hydrologic model**:** A model used to numerically simulate the physical process of how rainfall enters the regional conveyance system as infiltration and inflow (I/I).

Hydraulic model**:** A model of the actual pipes that convey the wastewater flows and I/I generated by the hydrologic model. The hydraulic model outputs flow depths and velocities within specific pipe segments and allows the evaluation of how the conveyance system performs under existing and future demands.

Basin: A geographic area that contributes flow to a specific location, usually a flow meter or facility. The two primary types of basins used in the assessment are ***model basins*** and ***mini basins***.

Model calibration**:** The process of adjusting model parameters so the model output matches the measured sewer flow for the same period.

Peak flow by return period**:** A statistical analysis related to the probability that a given flow will be equaled or exceeded in a given year. The 20-year peak flow has a 1 in 20, or 5% chance, of being exceeded in any given year.

The modeling required the following data:

- Flow data
  - Including varying groundwater conditions
- Rainfall and evaporation data
  - Including large rain storms to trigger I/I response
  - Including several storms to ensure simulation of different rainfall conditions
- Sewer basin data
  - Sewered area
  - Dry weather flow patterns
- Conveyance system specifications

Extensive wastewater flow and rainfall monitoring data, along with sewer basin data and a set of planning assumptions, were input into the MOUSE model. The data and modeling results provided the basis for establishing the current capacity conditions of the wastewater conveyance system and for projecting future flows. With this information, it was possible to identify the needed capacity related conveyance system improvements, which were documented in the RNA, and are further refined and documented in this memorandum. The various inputs and steps involved in the modeling analysis process are briefly summarized below.

1.2.1.2 Flow Data

To quantify both base and I/I flows, “model basins” and “mini basins” were identified and mapped by the County and local agencies:

- Model basins represent the sewered area flowing to a specific flow meter location. Each model basin consists of approximately 1,000 sewered acres and 100,000 lineal feet of pipe. There are 147 model basins. Some of the model basins straddle agency boundaries due to agreements between agencies to “pass through” or “wheel” flows to King County.

- Mini basins are a further sub-division of model basins that geographically isolate variation in I/I flow rates within the model basins. There are 775 mini basins. They average 150 acres with 22,000 lineal feet of pipe.

To measure and project base flow and I/I, approximately 800 flow meters[3] were installed throughout the regional service area to measure flows during dry-weather and wet-weather periods. Flows during dry-weather periods are typically base flows only. Wet-weather periods typically consist of both base flows and I/I. Metering flows during both dry and wet-weather periods makes it possible to develop separate measurements for base flow and I/I. The data gathered from flow meters were used to calibrate the hydrologic component of the conveyance system model and to establish non-storm flow patterns to characterize the base wastewater flow from specific portions of the service area.

Under specific weather conditions, the flow monitoring data gathered provide an accurate picture of current flows in local agency collection systems and the County’s regional conveyance

[3] More detailed information about the flow metering effort is documented in the *Wet Weather Flow Monitoring Technical Memoranda* (2000-01 and 2002-02) and the *Regional Needs Assessment Report*.

system. Projecting future flows required calibration of the hydrologic portion of the model to the measured flows.

1.2.1.3 Rainfall and Evaporation Data

Rainfall data throughout the regional wastewater service area were collected for the 2000-2001 and 2001-2002 wet seasons. Data were gathered from 64 rain gauges. The rain gauge data were used in combination with CALAMAR (Calcul de lames d'eau a l'aide due radar [calculating rain with the aid of radar]) to define varying rainfall intensities throughout the service area.

Rainfall data were used to calibrate the hydrologic model and establish storm flow patterns to characterize I/I patterns that cause peak flows during storm events. A continuous time series of rainfall data was a required input for the hydrologic modeling performed. Local rainfall data coupled with radar-based rainfall intensity data were used for the model calibration. For prediction of the 20-year peak I/I flow, a 60-year rainfall record was used as a reasonable approximation of future rainfall frequency and intensity.[4]

1.2.1.4 Sewer Basin Data

Sewered population and sewered area is information derived from a combination of available data and analyses of parcel data, aerial photos, zoning, and land-use records and plans. The information identifies the extent of current and future development within the sewered portion of the wastewater service area. Sewer basin data is GIS-based information about the service area previously unavailable at the level that it now exists. Along with its value for model calibration, sewer basin data allows growth assumptions to be clearly applied to future I/I and base flow scenarios.

1.2.1.5 Conveyance System Specifications

Conveyance system specifications include specific physical details (such as pipe sizes, elevations, pump station capacities, and connection points) about the conveyance system. Most of the necessary data were available from the County’s GIS database. Other details were provided by local agencies. The specifications are a key input into the hydraulic model, which measures and projects how different components of the conveyance system perform when subject to base flows and I/I following storm events. An overview of the hydraulic capacity analysis used to identify capacity constraints relative to peak flow demand is contained in Appendix A of this memorandum.

1.2.1.6 Planning Assumptions

Planning assumptions drive the timing of the projected capacity needs. Planning assumptions are applied by decade to each model basin and then compared to the capacity of the specific conveyance elements affected by the growth. Once the model assesses that elements of the system are under capacity relative to the demand, the year the exceedence is expected to occur is noted. For a detailed description of all planning assumptions, please see the RNA, *Appendix A5*.

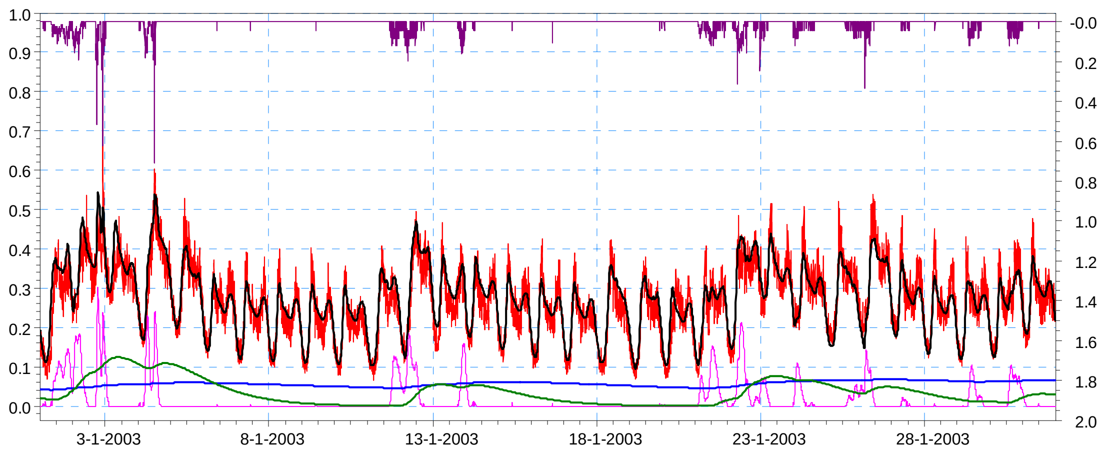
[4] Further details about the use of rainfall and evaporation data can be found in the *Regional Needs Assessment Report.*

1.2.1.7 The Model Calibration Process

Calibration of the model is necessary to test the accuracy of its outputs. Calibration was accomplished by comparing model results to actual measured flow data. Both the hydrologic and hydraulic components of the model were calibrated to the two wet seasons of flow data collected in 2000–2002, and to the dry-weather sewage flow pattern.

Calibration involved adjusting wet-weather flow parameters in the model until the model output matched actual measured wet-weather flows. The dry-weather flow calibration process involved taking measured sewer flow data from dry-weather periods and identifying diurnal patterns[5] based on measured flows on weekdays and weekends. The establishment of dry-weather diurnal patterns throughout the week allowed the model to distinguish between rainfall-induced peak flows and flows generated by periods of high water consumption in different parts of the service area. As an example, non-storm peak diurnal flows from the Sammamish Plateau on weekends are often higher than storm-induced peaks on weekdays.

Figure 1-5 below is a graphical example of how the calibrated model output matches the measured flow data for a variety of storms in the 2003 monitoring period.



Legend: Measured Flow; Measured Rainfall; Date Format (dd-mm-yyyy); Total Simulated Flow; Fast Response Component; Slow Infiltration; Rapid Infiltration

Figure 1-5. Comparison of Modeled Flow Data to Measured Flow Data

[5] Diurnal patterns are the regular rise and fall in daily consumptive use of water and production of wastewater. Varying land uses within sewer basins have a large impact on diurnal patterns and volume (i.e., different mixes of residential, commercial, and industrial land uses).

Once the models were calibrated, long-term simulations were run using the data inputs described above. The output from the long-term simulations was analyzed to determine the probability of a given peak flow being exceeded during a given year. This probability was then used to calculate the return period of peak flow. More detail on the calibration, dry-weather calibration, and estimation of peak flows is contained in Appendix A4 of the RNA.

1.2.1.8 Model Verification using the Hydraulic System Model

The next key element for modeling was inputting the flows into a hydraulic model of the County system of conveyance facilities (pipes, pumps, and storage) so that the current state of the system could be evaluated. This involved using the calibrated outputs from the hydrologic model along with base sewage flow data. The modeled flows were inputted into the hydraulic model in the appropriate physical locations. This was necessary because the model basins vary from a single connection point to the conveyance system to as many as nine connection points per model basin. Using flows from the calibration period allowed for spot checking of the original model basin calibrations by comparing combined model basin flows to flow measurements in the system. Comparing these flows allows the County to adjust both base flows and I/I model parameters to better characterize the base flow and I/I contributions to the system.

1.3 Conveyance Improvement Needs Based on System Condition

Another driver for conveyance facility improvement needs is the condition of individual facilities within the system. The condition of facilities is affected by their age, their material type(s), the micro environments they operate in, and the composition of the wastewater that each facility must convey during operation. Determination of the condition of a facility is a largely subjective exercise requiring interpretive skills and a broad knowledge of the following:

- How different conveyance system materials (metal, concrete, plastic, wood, etc.) perform over time
- How they are affected by the environment (slopes, soil conditions, etc.)
- How they are affected by the chemical composition of raw sewage that can contain corrosive agents such as hydrogen sulfide (H_2S) gas
- The inherent life-cycle of conveyance system materials and mechanical components

WTD has programs in place to identify, document, and repair adverse conditions in the system. These condition-related conveyance system maintenance needs have been identified through inspection and are documented in this memorandum. Over time, regular system inspection may identify new areas of deterioration in the system requiring conveyance system repair or replacement projects. While some condition deficiencies can be solved with spot-repairs and the use of on-call contractors, others may require capital investment to repair or replace the facility. Interior corrosion of sewer pipes is an example of a system condition that can require capital investment to repair and extend the useful life of a conveyance system facility. Figures 1-6 and 1-7 show the effects of H_2S corrosion in a sewer line and an application of a spray liner to repair corrosion.

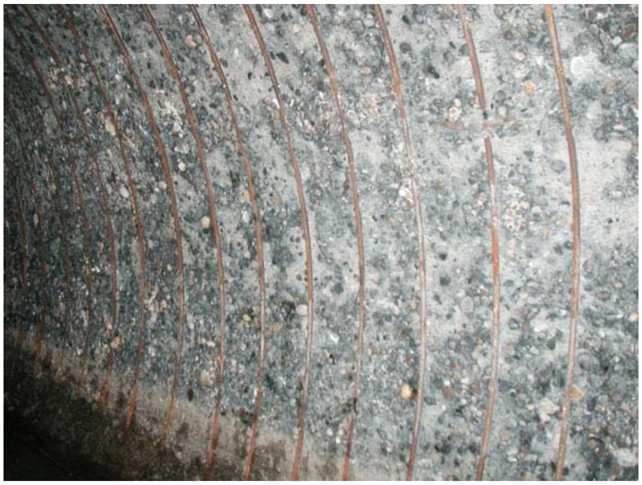


Figure 1-6. Years of exposure to wastewater and hydrogen sulfide gas (H_2S) have exposed reinforcement bars in some sewer pipes.

Figure 1-7. A construction worker applies part of plastic liner inside a corroded sewer pipe.

Conveyance System Components

Gravity Sewer: Pipes where wastewater flows passively due the effects of gravity. About 90% of the pipes in the King County collection system are gravity sewers.

Force Mains: Pipes used in conjunction with pump stations that convey wastewater under pressure. About 5% of the pipes in the King County collection system are force mains

Pressure Sewers: Pipes where wastewater flows under the effects of gravity but the pipe is under pressure. About 3% of the pipes in the King County collection system are pressure sewers.

Siphons: Siphons are used to convey wastewater under and across water bodies using gravity siphon effects. These pipes flow full and under pressure. Siphons make up about 2% of the pipes in the King County collection system.

Pump Stations: Facilities that pump wastewater flows from geographically low lying areas to a higher point where gravity flow can occur. There are 42 pump stations in the King County system

Regulator Station: Facilities that control the flow of wastewater using gates and valves to restrict or halt flow during peak flow events. Regulator stations back sewage up into storage facilities until flows can be safely conveyed by the downstream system. There are 19 flow regulator stations in the King County system.

This Section provides a brief overview of how the conveyance system is categorized for inspection, how the condition of the various facilities are assessed and documented, and how the nature and severity of the condition deficiency determine how the solution will be addressed.

1.3.1 Condition Inspection and Assessment Process

WTD operates a large and complex sewer conveyance system with more than 275 miles of sewer lines ranging in diameter from 12 inches to 14 feet, the oldest of which was built in 1890. The conveyance system consists of gravity sewers, force mains, pressure sewers, siphons, pump stations, and regulator stations that transport wastewater to the regional treatment plants (see sidebar for descriptions of the conveyance system components). The complexity of the system requires different types of expertise to maintain, inspect, determine improvement needs, and appropriately prioritize those improvement needs.

1.3.1.1 System Condition Analysis

Analyzing the condition of conveyance facilities has three primary purposes:

- Determine to the extent possible system conditions that will warrant capital investment.
- See if and where deteriorating conditions exist near known capacity needs.
- Check if facilities identified as having cost-effective I/I reduction projects in the service area have conditions that will result in the need to replace a conveyance facility regardless of the ability to cost-effectively reduce I/I flows and capacity demand.

This analysis breaks the system into three groups of components:

- Gravity sewers
- Force mains, pressure sewers, and siphons
- Pump stations and regulator stations

The breakdown is along the lines of WTD work units responsible for inspecting and directing maintenance of given facilities. The Facilities Inspection Unit in Asset Management inspects gravity sewers, force mains, pressure sewers, and siphons. The Offsite Facilities Groups at the West Point and South Treatment Plants inspect and maintain the pump and regulator stations.

Gravity systems are inspected using a variety of techniques and technologies ranging from manual visual inspections to video analysis. On average, gravity sewers are video inspected on a 10-year cycle. If deteriorating conditions are identified during inspection, a more frequent inspection schedule for the site is implemented. If conditions are identified that require immediate attention to repair, there are a number of ways for repairs to be addressed depending upon the scope and scale of the need.

Force mains, pressure sewers, and siphons present challenges to inspection due to the full pipe pressurized conditions in which they operate. Traditional video inspection techniques typically require systems to be emptied or at least have their flows reduced. Inspecting pressurized systems often requires temporary shutdown of portions of the conveyance system. These temporary shutdowns can limit the time available for inspections. Some portions of the system cannot be shutdown without risking wastewater overflows. As a result, many force mains, pressure sewers, and siphons have not been thoroughly inspected on a regular basis. New techniques using sonar and other technologies are becoming available to inspect these facilities more thoroughly without taking the systems off line. As these types of facilities can be regularly inspected, additional conveyance needs due to deteriorating condition may be identified.

Pump and regulator stations are monitored continuously by the offsite and onsite treatment plant staff through the SCADA (Supervisory Control and Data Acquisition) and Metro-Tel systems. These two telecommunication and computer systems provide redundant oversight of a variety of facility conditions including pump performance, wastewater flow levels, and emergency notifications of equipment malfunction. Regularly scheduled inspection and maintenance of the station equipment is performed by offsite staff. Once it is determined that the mechanical equipment at the stations require replacement or upgrade, the projects are sent either to the Asset Management or Major Capital program for implementation depending upon the scope of the replacement /upgrade.

The majority of needs identified based on the condition of conveyance facilities are addressed through Asset Management. Projects identified have an Engineering Work Request (EWR) prepared. Identified needs compete for funding based on a number of criteria and prioritization of the project's relative need.

WTD is currently involved in development of an agency-wide Asset Management Program that will allow business case evaluations for all asset management decisions. Business case evaluations compare the long term cost of maintaining existing assets to the cost of replacing the assets and incurring lower maintenance costs over the same period. An Asset Management taskforce consisting of WTD staff is currently working to generate pilot case studies for applying business case evaluations to Asset Management and Major Capital projects. It is expected that the taskforce's work will be completed incrementally between 2005 and 2010. The approximate five-year timeframe for completing the work will allow for gathering and analyzing data, completing inspections, documenting repair information, and developing cost data. The taskforce conclusions are expected to be integrated in an update of the region's conveyance system plan at that time.

Section 4 of this memorandum provides further detail about system condition assessment and examples of condition-related needs currently identified throughout the regional conveyance system.

1.4 Conveyance System Age

The regional conveyance system includes pipes and other facilities that were built as early as 1890, with substantial additions being made through present day. Twenty percent of the pipes in the system are over 50 years old and will continue to age in the coming decades. As the system ages, it deteriorates. Ongoing inspection, maintenance, and repair activity has kept the system operating safely, but portions of the system will reach the end of their theoretical useful life between now and 2050.

The useful life of conveyance facilities varies depending upon the materials used in construction, the environment it operates in, and the frequency and effectiveness of maintenance and repair work. Wastewater conveyance systems are subject to internal corrosion from biochemical processes in the sewage and external factors such as structural loads and galvanic corrosion.

Cathodic, or galvanic, corrosion is caused by the flow of electrical current from a more active metal (anode) to a less active metal (cathode) in the same environment. Ferrous (iron and steel) materials used in force mains, siphons, and pressure sewers are highly vulnerable to galvanic corrosion.

Concrete pipe is susceptible to corrosion from hydrogen sulfide gasses generated by the wastewater as it flows through the system.

The useful life of different conveyance facilities also depends upon whether the component has mechanical equipment associated with its operation. For example, the pumps and control systems at a pump station have a life cycle of 15 to 25 years, while the station structure and fixed components are likely to have a life cycle of 50 to 75 years and are sized to handle projected flows for that period. The life cycle of either mechanical equipment or fixed assets can be, and often are, extended beyond their expected useful life

Section 4 of this technical memorandum contains information about the age of all conveyance system facilities within the regional system. The age of each conveyance facility was determined by the recorded construction year. In some cases significant maintenance and capital work has been performed to extend the useful life of the asset.

Databases containing information about pipe material, age, inspection, and repair history have been used to identify and categorize facilities by age and material type.

The different conveyance facilities have also been split into the following general material categories and ranked by age:

- Concrete sewers
- Iron and steel (ferrous materials)
- Brick
- Plastic (fiberglass, PVC, High Density Poly Ethylene [HDPE])
- Miscellaneous, including wood, clay, and asbestos